

# COCPIT: Collaborative Activity Planning Software for Mars Perseverance Rover

Ivy Deliz

NASA Ames Research Center  
ASRC Federal

Andrea Connell

Jet Propulsion Laboratory  
California Institute of Technology

Chet Joswig

Jet Propulsion Laboratory  
California Institute of Technology

Bob Kanefsky

NASA Ames Research Center  
San Jose State University Research Foundation

Jessica Marquez

NASA Ames Research Center

# COCBIT: Collaborative Activity Planning Software for Mars Perseverance Rover

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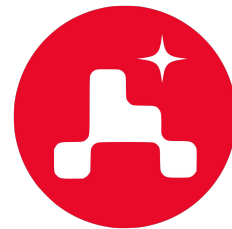
AUTONOMOUS SCHEDULING

SEQUENCING

SUMMARY

IEEE Aerospace Conference  
Big Sky, MT 2022

# Introduction



- Perseverance Rover landed on Mars February 2021
- Surface operations team members are distributed between North America and Europe
- COCPIT is part of the Mars 2020 Ground Data Systems

# COCPIT

## Component-based Campaign Planning, Implementation and Tactical



### Responsible for

- Activity planning
- Continuously verifying constraints
- Document Science Intent
- Model data and power resources
- APIs to interface with GDS tools
- Target association

# Architecture

Collaborative web-application

Extends and customizes the  
Playbook planning and execution  
tool developed at NASA Ames  
Research Center



## Dev Stack

- Frontend
  - JavaScript, HTML, CSS, Backbone.js, d3, svg, Web Sockets
- Backend
  - Node.js, nginx
- Database
  - Redis for temporary storage
- Infrastructure
  - Docker, AWS, XML for permanent storage in S3, Single Sign-On Authentication Layer, Elastic Search

Marquez, J.J., Hillenius, S., Deliz, I., Kanefsky, B., Zheng, J., and Reagan, M.,  
“Increasing Crew Autonomy for Long Duration Exploration Missions:  
Self-Scheduling” in IEEE Aerospace Conference, 2017

# Planning Phases

COCPIT supports all planning phases

1. Parcel Development
  - Define and validate reusable Activities
2. Strategic Planning
  - Create plan fragment templates
  - Consider timing constraints
  - Assess heating requirements and resources
3. Campaign Implementation
  - Look-Ahead Plan for the next ~5 Sols
  - Includes communication passes
  - Ensure progression of science goals
  - Evaluate options, guide tactical planning
4. Tactical Uplink
  - Plan next sol(s) to be executed by the rover
  - Incorporate changes based on received data (i.e. status and latest images)
  - Ensure constraints are met
  - Generate sequences to send to rover
5. Tactical Downlink
  - View currently executing plan
  - Receive and analyze data

# Navigator

COCBIT Navigator

+ New

Search by...

Logout (joswig)

	Name ▲	Hyperlink	Last Modified
PINNED			
	ActID	<a href="#">cocpit_url/navigator/?folder=actid</a>	18:36 May 20, 2021
	Component Library	<a href="#">cocpit_url/navigator/?folder=component-library</a>	09:41 Oct 12, 2020
	Conjunction	<a href="#">cocpit_url/navigator/?folder=conjunction</a>	11:49 Sep 13, 2021
	FTA	<a href="#">cocpit_url/navigator/?folder=fta</a>	23:56 Jun 10, 2021
	HGA Heating	<a href="#">cocpit_url/navigator/?folder=hga-heating</a>	04:03 May 21, 2021
	LAP	<a href="#">cocpit_url/navigator/?folder=lap</a>	11:32 Feb 10, 2021
	Look_Ahead_Plan	<a href="#">cocpit_url/?plan=unique_id</a>	08:05 Oct 12, 2021
	P6 CL (v1629930542)	<a href="#">cocpit_url/?complib=1629930542</a>	15:58 Oct 01, 2021
	SFP/Runout Plan Layouts	<a href="#">cocpit_url/navigator/?folder=anomaly</a>	23:16 Feb 07, 2021
	Sol00213_Tactical	<a href="#">cocpit_url/?plan=unique_id</a>	01:16 Oct 12, 2021
	Sol00214_Tactical	<a href="#">cocpit_url/?plan=unique_id</a>	11:14 Oct 08, 2021
	Sol00216_Tactical	<a href="#">cocpit_url/?plan=unique_id</a>	16:50 Oct 11, 2021
	Sol00217_Tactical	<a href="#">cocpit_url/?plan=unique_id</a>	04:41 Oct 08, 2021
	Sol00224_Tactical	<a href="#">cocpit_url/?plan=unique_id</a>	19:07 Oct 06, 2021
	Sol00231_Tactical	<a href="#">cocpit_url/?plan=unique_id</a>	20:10 Oct 11, 2021
	Tactical	<a href="#">cocpit_url/navigator/?folder=tactical</a>	14:43 Jan 13, 2021
	workspace	<a href="#">cocpit_url/navigator/?folder=workspace</a>	09:41 Oct 12, 2020

- Companion application
- Management of plans, component libraries and folders
- Supports planning workflows
  - Bookmarking
  - Plan level operations
  - Color tagging
- Query search for metadata and archival information

# Component Library

- Collection of reusable components with resource information (energy, data, duration)
- Planning units for Campaign Implementation and Tactical Planning phases

COCBIT - CL v23145					
Component Library Version: kry05pfl					
Component Name ▲	Author	Total Energy	Total Data	Critical Data	Duration
ATM - MEDA Background Noon	jbeek	2.5 Whrs	0.0 Mb	0.0 Mb	00:10:51
ATM - MEDA Background Odd Hour	mtrautma	200.8 Whrs	0.0 Mb	0.0 Mb	14:33:12
ATM - MEDA Load OT	jbeek	1.1 Whrs	0.0 Mb	0.0 Mb	00:10:00
ATM - MOXIE	jbeek	857.7 Whrs	34.1 Mb	34.1 Mb	03:45:46
ATM - NCAM Cloud Survey	klichten	7.3 Whrs	24.6 Mb	0.0 Mb	00:08:15
ATM - NCAM Dust Devil Movie - M	mtrautma	3.9 Whrs	25.8 Mb	0.0 Mb	00:11:00
ATM - NCAM Dust Devil Movie - S	mtrautma	3.8 Whrs	25.8 Mb	0.0 Mb	00:10:30
ATM - NCAM Dust Devil Movie Quick	mtrautma	7.3 Whrs	24.6 Mb	0.0 Mb	00:08:15
ATM - NCAM Dust Devil Movie w/ mic	jbeek	6.0 Whrs	92.6 Mb	0.0 Mb	00:11:04
ATM - NCAM Dust Devil Survey	klichten	7.7 Whrs	18.4 Mb	0.0 Mb	00:09:10
ATM - NCAM RSM ENV	mtrautma	7.3 Whrs	24.6 Mb	0.0 Mb	00:08:15

COCBIT - CL 23145

Author

+ New Component

Deliver

Go to Component Library

Draft Component

Duplicate Component

Component:

ATM - NCAM Dust Devil Movie w/ mic

Activity Group Network for ATM - NCAM Dust Devil Movie w/ mic:

+ Add Activity Group

Dust devil s... 4

Relative Activity Timeline for Dust devil survey Small 1:

Zoom In

Zoom Out

+ Add Activity

SCAM Sunsaf

SCAM SeqWait for NCAM pointi

NCAM RSM ENV

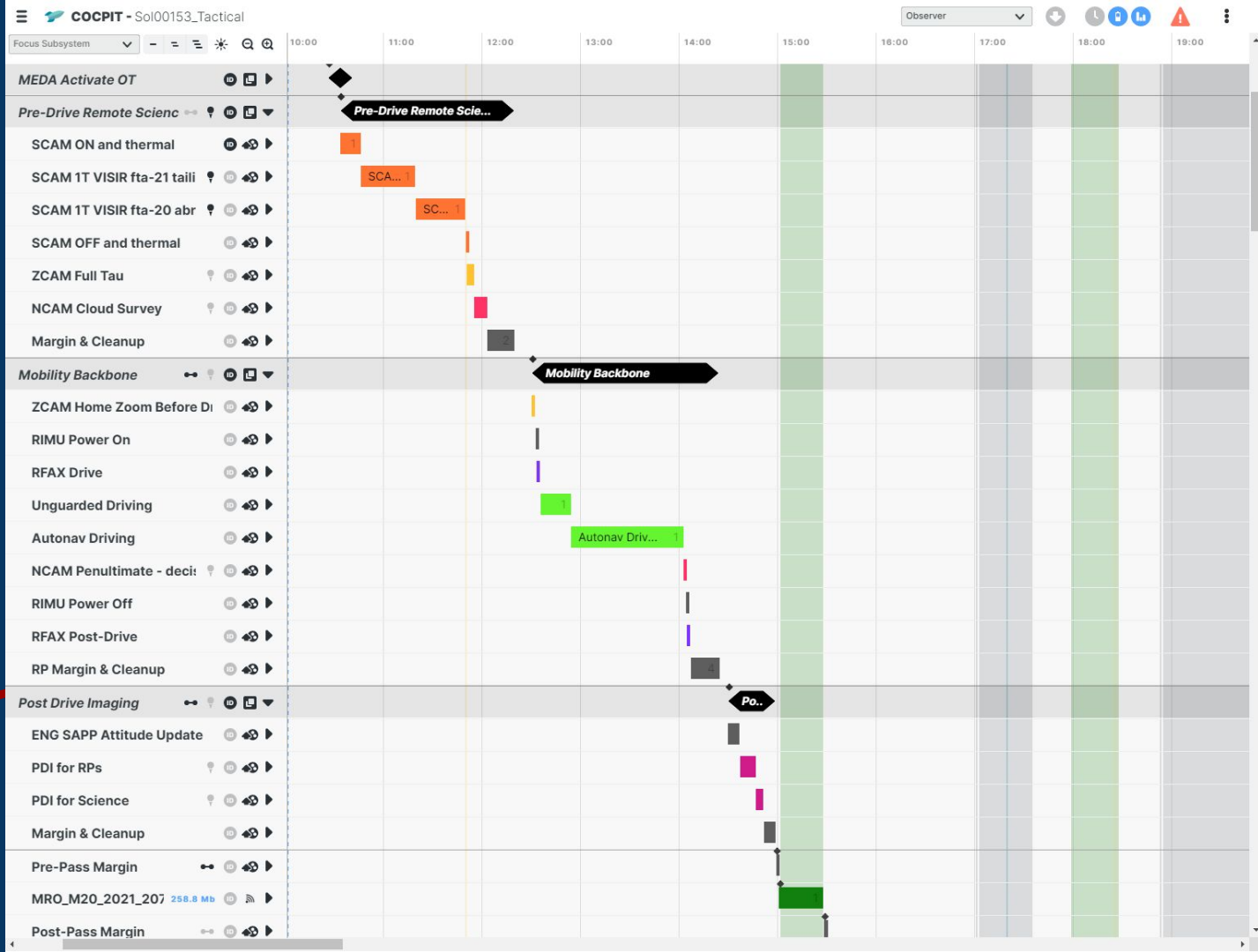
SCAM 1x1 MICROPHONE

+00:00

UNKNOWN DATE

# Timeline

- Main view to manipulate and review the plan
- Hierarchical and chronological order
- Row labels have shortcuts to important information
- Vertical Overlays show comm passes and when rover is asleep
- Blue dash lines show handovers
- Time window constraint representation



# Plan Structure

Post-Drive Imaging	📍 ID 📄 ▼	Post-Dr...	
PDI for RPs	📍 ID 🔄 ▼	■ A	
FHAZ Workspace	ID 🔄	■	
NCAM Workspace	📍 ID 🔄	■	
RHAZ Ultimate	ID 🔄	■	
NCAM Drive Direction	📍 ID 🔄	■	
ZCAM PDI Workspace	📍 ID 🔄 ▼		■
ZCAM workspace mosaic P19 L0 R0 Z63	📍 ID 📄		■
PDI for Science	📍 ID 🔄 ▼		■
Complete the 360	📍 ID 🔄		■
Margin & Cleanup	ID 🔄 ▼		■ 2
Margin	ID 🔧		■
Cleanup	ID 🔧		■

- Planning Unit Types
  - Components contain Activity Groups
  - Activity Groups contain Activities
  - Activities are of many different Types
- Components are plan fragments that can be added to and removed from plan
- Timeline shows Activity Groups and Activities as children (not Components)
- During planning, Activity Groups can be grouped into Merge Sets (back rectangle with diamond corners)

☰  **COCBIT** - Sol00153\_Tactical

- Alternate view showing Components, Activity Groups and Activity hierarchy
- Column per Sol
- Shows Planning Units outside of the bounds of execution
- Per-Sol Data and Power Resources

		COCBIT - Sol00153_Tactical	PASTE	SEL					
Pre Plan		+ Handover Sol 153			+ Handover Sol 154				Post Plan
Copilot Activity Groups	⚙ ▶	Copy of Copy of Copy of Copy of Copy ⚙ ▶			EO - LGA Nominal Beep 📶 ▶				[R] MVR
ATM - MEDA Background Extended	🔴 ▶	Copy of Copy of Copy of Copy of Cop! 📶 ▶			EO - Engineering Keepout ⚙ ▶				[R] ODY
Sol_0153_AM_HGA_DFE	📶 ▶	Copy of Copy of Copy of Copy of Copy ⚙ ▶			UTIL - Geometric Events 🟡 ▶				[R] TGO
EO - Uploss Timer	⚙ ▶	IO - SCAM ON/OFF (All) 🟠 ▶			ATM - MEDA Background Extended 🔴 ▶				[R] MRG
		ATM - MEDA Activate OT 🔴 ▶			Copy of UTIL - Placeholder - CPU On ⚙ ▶				[R] Sol
		Copy of UTIL - Placeholder - CPU On ⚙ ▶			Copy of ATM - NCAM Dust Devil Sur 🔦 🔴 ▶				[R] MRG
		UTIL - Margin & Cleanup ⚙ ▼			Copy of ATM - Tau ZCAM Full [Z] 🔦 🟡 ▶				[R] ODY
		Margin & Cleanup ID MAO ▼			IO - SCAM ON/OFF (IR/RMI/MIC) 🟠 ▶				[R] TGO
		Margin ID 🔗			RS - SCAM VISIR Target [Su] 🔦 🟠 ▶				[R] MRG
		Cleanup ID 🔗			Copy of RS - SCAM VISIR Target [Su] 🔦 🟠 ▶				[R] ODY
		RS - SCAM VISIR Target [Su] 🔦 🟠 ▶			Copy of IO - SCAM LIBS Calibration Sin 🟠 ▶				[R] Sol
		ATM - MEDA Background Extended 🔴 ▶			Copy of IO - SCAM LIBS Calibration Sin 🟠 ▶				[R] MRG
		RS - SCAM VISIR Target [Su] 🔦 🟠 ▶			Copy of UTIL - Margin & Cleanup ⚙ ▶				[R] ODY
		UTIL - Geometric Events 🟡 ▶			UTIL - Placeholder - CPU On ⚙ ▶				[R] TGO
		Sol 153 Resources ▼			Sol 154 Resources ▼				[R] MRG
		Modeled Incoming SOC 96.4%			Modeled Incoming SOC 83.7%				[R] ODY
		Override Incoming SOC %			Override Incoming SOC %				[R] Sol
		Modeled Outgoing SOC 83.8%			Modeled Outgoing SOC 58.6%				
		Minimum Usable SOC 65.6% 16:30:32			Minimum Usable SOC 52.5% 06:08:50				
		Maximum RPAM 19.7 A 11:20:28			Maximum RPAM 19.8 A 03:00:00				
		Max Battery Load Current 16.8 A 11:24:02			Max Battery Load Current 16.5 A 03:00:00				
		Available Decisional DV 68.5 Mb			Available Decisional DV 613.3 Mb				
		Decisional Pass DV 68.5 Mb (MRO_M20_2...)			Decisional Pass DV 613.3 Mb (MVN_M20_2...)				
		Decisional Bin Reached 68			Decisional Bin Reached 78				
		Total Acquired DV 2529.6 Mb			Total Acquired DV 442.2 Mb				

# Details Panel

- Selection-aware panel for editing
- Each planning unit type shows the relevant sections, operations and parameters for its type
- Respect permissions by role and type of planning unit
- Multiselect shows metrics and supported operations for selection
- Same details panel available in all COCPIT views

Activity Group

MEDA Session 15

MEDA Background Extended

Start Time

Sol 153 15:00:00

End Time

Sol 153 16:05:30

Duration

01:07:19

Constraints

MERGE

Pin

Start

Sol 153

15:00:00

Window

Start

Sol

End

Sol

Dependency

Resource Effects

Energy

Total Energy

8.0 Whrs

Data Effects

MEDA\_SDP\_Data\_S...

10.5 Mb

Parameters

Show Expert Parameters

Seq\_ID

Mandatory

Mstr\_Seq\_Activate

Arm\_Heating

Default

Bit\_Carousel\_Heati...

Default

Multi Select

Total Duration

02:14:57

Start Time

Sol 153 13:00:00

Gap

00:55:40

Span

03:10:37

Selected (2)

MEDA Session 13

MEDA Session 15

WATERFALL

COMPRESS RIGHT

DEPENDENCY

MERGE

COPY

DELETE

Current Constraints

# Data Modeling

- COCPIT models data generated, reprioritized, retransmitted and downlinked by rover
- Activity parameters contribute to the calculation of data (using formulas in AD)
- Crucial to understand when the data will be available for analysis Earth
  - Decisional Data is data needed for next tactical planning cycle
- Activities show data contributions
- Data Resource Panel shows aggregated values per criticality at the plan-level and a specific time in the plan

Data	
Decisional Data Volume	
Available	63.443 Mb
Modeled	77.04 Mb
Decisional Bin	
Goal	39
Reached	52
Acquired Data Volume	
Maximum Allowable	3500 Mb
Total Modeled	3262.103 Mb
Data_Critical	569.017 Mb
Data_High	774.613 Mb
Data_Medium	905.779 Mb
Data_Low	995.833 Mb
Data_Lowest	16.861 Mb
Onboard Data Volume	
Maximum Allowable	28588 Mb
Modeled Total	19355.163 Mb

# Collaboration & Interfaces

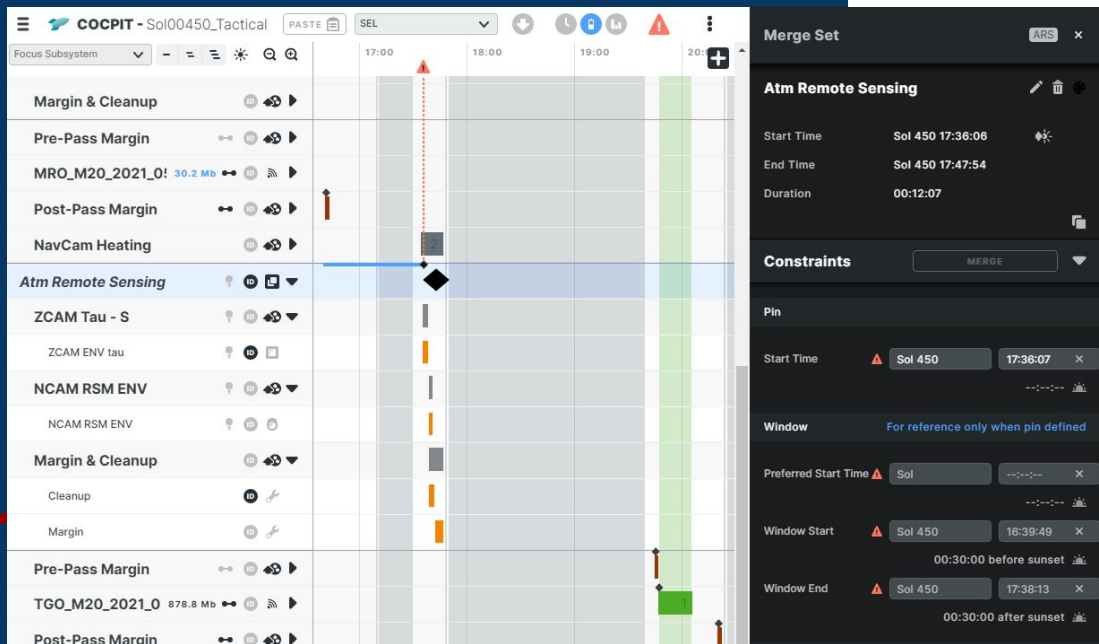
## Collaboration

- Team Members around the world can access the live plan with a web browser
  - Changes are distributed to all clients automatically to keep them up to date
- Role-based permissions control actions

## Interfaces

- COCPIT's Application Programming Interfaces (APIs) allow other tools to submit changes programmatically
- A pub/sub service sends notifications to tools that are interested in receiving plan changes
- Plan Patch allows Rover Planners to optimize rover motions by adding, removing and reordering activities with a bulk change operation

# Temporal Constraint Network



## Constraint Types

- Pin to start at a specific time
- Execution Window
  - Earliest Start, Latest End, Preferred Start
- Dependency
  - Start before or after another planning unit

COCPIT uses a Temporal Constraint Network to evaluate the set of constraints in the plan and warns users if they are inconsistent or circular.

# Autonomous Scheduling

## Planning vs. Scheduling

- COCPIT users are responsible for planning: selecting desired activities, setting parameters and constraints
- An autonomous scheduler determines actual start times for each planning unit

## Scheduling Considerations

- Predicted duration
- Timing and dependency constraints
- Data volume and power limits
- Mechanical state requirements and effects
- Allowable parallelism

## On the ground and on-board

- Ground software Copilot is heavily integrated with COCPIT
- Perseverance flight software will also support autonomous scheduling
- Both are informed by data in the COCPIT plan

# Sequencing

- After plan is finalized, it is used to generate the sequences that run on the rover.
- Individual activities are converted to sequences. Activity parameters determine which commands and arguments are generated.
- The structure of the plan is used to build master and submaster sequences that coordinate the flow of execution of other sequences.
  - Timing constraints map to commands to pause until a given time.
  - Merge Sets and Groups map to submaster sequences.
  - Wake and Sleep activities map to commands instructing the spacecraft when to wake up and shut down.

# Summary

As missions become more complex, tools must allow more integration, automation and collaboration to enable less work hours for operators and more science on Mars.

COCPIT and Playbook are modern planning and scheduling tools paving the way for software supporting humans and robotic exploration of Moon, Mars and beyond.

Thank you to the COCPIT management, design, test, infrastructure, and development team for working tirelessly to make this software successful. Anthony Robertson, Ryan Goetz, Kathryn Yu, Roxana Gonzalez Burgos, Joshua Camacho, Jimin Zheng, Sara Schnadt, Adrian Galvin, Basak Alper Ramaswamy, Guy Pyrzak, Hoan Luu, Natalie Rezek, Jon Blossom and Usha Guduri.

